

Claims

What I claim is:

1. A fine-grained iron base alloy in which the ASTM grain size number is greater than or equal to 5, consisting essentially of (wt. %): $0.05 < C < 0.15$; $7.5 < Cr < 15$; $2 < Ni < 5$; $Co < 4$; $Cu < 1.2$; $Mn < 5$; $Si < 1$; $(Mo + W) < 4$; $0.01 < Ti < 0.75$; $Zr < 1.6$; $Ta < 3.2$; $Hf < 3.2$; $0.135 < (1.17Ti + 0.6Zr + 0.31Ta + 0.31Hf) < 1$; $N < 0.02$; $Al < 0.2$; Al and Si both present such that $(Al + Si) > 0.01$; each of B, Ce, Ca, Mg, Sc, Y, La, and Be less than 0.1; $P < 0.1$; $S < 0.03$; each of Sn, Sb, O, Pb and other impurities less than 0.04; and the balance essentially iron.
2. The iron base alloy of claim 1, wherein the alloy is in a hot worked condition.
3. The iron base alloy of claim 1, wherein the alloy is in a hot rolled condition and formed into a tubular product.
4. The iron base alloy of claim 1, wherein the alloy is in a hot worked condition and formed into a tubular product.
5. A fine-grained iron base alloy in which the ASTM grain size number is greater than or equal to 5, consisting essentially of (wt. %): $0.05 < C < 0.15$; $7.5 < Cr < 15$; $2 < Ni < 5$; $Co < 4$; $Cu < 1.2$; $Mn < 5$; $Si < 1$; $(Mo + W) < 4$; $0.01 < Ti < 0.75$; $Zr < 1.6$; $Ta < 3.2$; $Hf < 3.2$; $0.135 < (1.17Ti + 0.6Zr + 0.31Ta + 0.31Hf) < 1$; $V < 2$; $Nb < 1$; $N < 0.02$; $Al < 0.2$; Al and Si both present such that $(Al + Si) > 0.01$; each of B, Ce, Ca, Mg, Sc, Y, La, and Be less than 0.1; $P < 0.1$; $S < 0.03$; each of Sn, Sb, O, Pb and other impurities less than 0.04; and the balance essentially iron.
6. The iron base alloy of claim 5 wherein the alloy is in a hot worked condition.

7. The iron base alloy of claim 5, wherein the alloy is in a hot rolled condition and formed into a tubular product.
8. The iron base alloy of claim 5, wherein the alloy is in a hot worked condition and formed into a tubular product.
9. A method of producing a fine-grained iron base alloy, comprising:
preparing an iron base alloy consisting essentially of (wt. %): $0.05 < C < 0.15$; $7.5 < Cr < 15$; $2 < Ni < 5$; $Co < 4$; $Cu < 1.2$; $Mn < 5$; $Si < 1$; $(Mo + W) < 4$; $0.01 < Ti < 0.75$; $Zr < 1.6$; $Ta < 3.2$; $Hf < 3.2$; $0.135 < (1.17Ti + 0.6Zr + 0.31Ta + 0.31Hf) < 1$; $V < 2$; $Nb < 1$; $N < 0.02$; $Al < 0.2$; Al and Si both present such that $(Al + Si) > 0.01$; each of B, Ce, Ca, Mg, Sc, Y, La, and Be less than 0.1; $P < 0.1$; $S < 0.03$; each of Sn, Sb, O, Pb and other impurities less than 0.04; and the balance essentially iron; and thermal mechanically treating the iron base alloy by a process comprising: austenitizing the iron base alloy at a temperature above $1000^{\circ}C$; hot working the alloy at a temperature greater than $1000^{\circ}C$ to impart a true strain of greater than 0.15 (15 %); and cooling the alloy to room temperature to obtain a fine-grained martensitic microstructure in which the ASTM grain size number is greater than or equal to 5.
10. The method of claim 9, wherein hot working the iron base alloy comprises hot rolling the iron base alloy at a temperature above about $1000^{\circ}C$ to impart the true strain of greater than 0.15 (15%).
11. The method of claim 9, wherein hot rolling the iron base alloy further comprises forming the iron base alloy into a tubular product.

12. The method of claim 9, wherein hot working the iron base alloy further comprises forming the iron base alloy into a tubular product.

13. The method of claim 9, further comprising heat treating the iron base alloy after the iron base alloy is cooled to room temperature and retaining a fine grain size in which the ASTM grain size number is greater than or equal to 5.

14. The method of claim 13, wherein heat treating the iron base alloy after the iron base alloy is cooled to room temperature further comprises tempering the iron base alloy.

15. The method of claim 13, wherein heat treating the iron base alloy after the iron base alloy is cooled to room temperature further comprises austenitizing, quenching and tempering the iron base alloy.

16. The method of claim 13, wherein heat treating the iron base alloy after the iron base alloy is cooled to room temperature further comprises normalizing and tempering the iron base alloy.

17. The method of claim 13, wherein heat treating the iron base alloy after the iron base alloy is cooled to room temperature further comprises normalizing the iron base alloy.

18. The method of claim 13, wherein heat treating the iron base alloy after the iron base alloy is cooled to room temperature further comprises austenitizing and quenching the iron base alloy.

19. A fine-grained iron base alloy in which the ASTM grain size number is greater than or equal to 5, consisting essentially of within a range of plus or minus 15% of the following nominal amounts (wt. %): 0.09 C, 10.7 Cr, 2.4 Ni, 0.5 Mn, 0.5 Mo, 0.15 Si, 0.024 Al, 0.37 Ti and the balance essentially iron and impurities.
20. The iron base alloy of claim 19, wherein the iron base alloy is in a hot worked condition.
21. The iron base alloy of claim 19, wherein the iron base alloy is in a hot rolled condition.
22. The iron base alloy of claim 19, wherein the iron base alloy is in a hot rolled condition and formed into a tubular product.
23. The iron base alloy of claim 19, wherein the iron base alloy is in a hot worked condition and formed into a tubular product.
24. A fine-grained iron base alloy in which the ASTM grain size number is greater than or equal to 5, consisting essentially of (wt. %) about 0.09 C, about 10.7 Cr, about 2.4 Ni, about 0.5 Mn, about 0.5 Mo, about 0.15 Si, about 0.024 Al, about 0.37 Ti, and the balance essentially iron and impurities.
25. The iron base alloy of claim 24, wherein the iron base alloy is in a hot worked condition.
26. The iron base alloy of claim 24, wherein the iron base alloy is in a hot rolled condition.

27. The iron base alloy of claim 24, wherein the iron base alloy is in a hot rolled condition and formed into a tubular product.
28. The iron base alloy of claim 24, wherein the iron base alloy is in a hot worked condition and formed into a tubular product.
29. A fine-grained iron base martensitic alloy in which the ASTM grain size number is greater than or equal to 5, consisting essentially of (wt. %): $0.05 < C < 0.15$; $7.5 < Cr < 15$; $1 < Ni < 5$; $Co < 10$; $Cu < 5$; $Mn < 5$; $Si < 1.5$; $(Mo + W) < 4$; $0.01 < Ti < 0.75$; $Zr < 1.6$; $Ta < 3.2$; $Hf < 3.2$; $0.135 < (1.17 Ti + 0.6 Zr + 0.31 Ta + 0.31 Hf) < 1$; $V < 2$; $Nb < 1$; $N < 0.05$; $Al < 0.2$; $(Al + Si) > 0.01$; each of B, Ce, Ca, Mg, Sc, Y, La, and Be less than 0.1; $P < 0.1$; $S < 0.03$; each of Sn, Sb, O, Pb and other impurities less than 0.04; and the balance essentially iron.
30. The iron base alloy of claim 29, wherein the iron base alloy is in a hot worked condition.
31. The iron base alloy of claim 29, wherein the iron base alloy is in a hot rolled condition and formed into a tubular product.
32. The iron base alloy of claim 29, wherein the iron base alloy is in a hot worked condition and formed into a tubular product.
33. A method of producing a fine-grained iron base alloy that comprises preparing an iron base alloy consisting essentially of (wt. %): $0.05 < C < 0.15$; $7.5 < Cr < 15$; $1 < Ni < 5$; $Co < 10$; $Cu < 5$; $Mn < 5$; $Si < 1.5$; $(Mo + W) < 4$; $0.01 < Ti < 0.75$; $Zr < 1.6$; $Ta < 3.2$; $Hf < 3.2$; $0.135 < (1.17 Ti + 0.6 Zr + 0.31 Ta + 0.31 Hf) < 1$; $V < 2$; $Nb < 1$; $N < 0.05$; $Al < 0.2$; $(Al + Si) > 0.01$; each of B, Ce, Ca, Mg, Sc, Y, La, and Be less than 0.1; $P < 0.1$; S

< 0.03; each of Sn, Sb, O, Pb and other impurities less than 0.04; and the balance essentially iron; and thermal mechanically treating by austenitizing it at a temperature above 1000°C, hot working the alloy at a temperature greater than 1000°C to impart a true strain of greater than 0.15 (15 %) and cooling the alloy to room temperature to obtain a fine-grained martensitic microstructure in which the ASTM grain size number is greater than or equal to 5.

34. The method of claim 33, wherein hot working the iron base alloy comprises hot rolling the iron base alloy at a temperature above about 1000°C to impart the true strain of greater than 0.15 (15%).

35. The method of claim 33, wherein hot rolling the iron base alloy further comprises forming the iron base alloy into a tubular product.

36. The method of claim 33, wherein hot working the iron base alloy further comprises forming the iron base alloy into a tubular product.

37. The method of claim 33, further comprising heat treating the iron base alloy after the iron base alloy is cooled to room temperature and retaining a fine grain size in which the ASTM grain size number is greater than or equal to 5.

38. The method of claim 37, wherein heat treating the iron base alloy after the iron base alloy is cooled to room temperature further comprises tempering the iron base alloy.

39. The method of claim 37, wherein heat treating the iron base alloy after the iron base alloy is cooled to room temperature further comprises austenitizing, quenching and tempering the iron base alloy.

40. The method of claim 37, wherein heat treating the iron base alloy after the iron base alloy is cooled to room temperature further comprises normalizing and tempering the iron base alloy.

41. The method of claim 37, wherein heat treating the iron base alloy after the iron base alloy is cooled to room temperature further comprises normalizing the iron base alloy.

42. The method of claim 37, wherein heat treating the iron base alloy after the iron base alloy is cooled to room temperature further comprises austenitizing and quenching the iron base alloy.